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APPLICATION NUMBER: ***60/533,140***
FILING DATE: ***December 30, 2003***
RELATED PCT APPLICATION NUMBER: ***PCT/US04/41239***

UNITED STATES PATENT AND TRADEMARK OFFICE DEPARTMENT OF COMMERCE

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16563 U.S. PTO
123003

PTO/SB/16 (08-03)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

031356 U.S. PTO
60/533140
123003

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
William John	Testin	Indianapolis, Indiana

☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

MODIFIED CONTROL FOR THERMISTOR OPERATED DC FAN

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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OR

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 5 ☐ CD(s), Number ____

☒ Drawing(s) *Number of Sheets* 4 ☐ Other (specify) ____

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

☒ The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 07-0832

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____.

Respectfully submitted,
SIGNATURE [signature]

Date: Dec. 30, 2003

TYPED or PRINTED NAME: Robert B. Levy

REGISTRATION NO. *(if appropriate)*: 28,234

Docket Number: PU030338

TELEPHONE: 609/734-6820

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET

Additional Page

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Docket Number

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)

[Page 2 of 2]

Number 2 of 2

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FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160

Complete if Known	
Application Number	
Filing Date	December 30, 2003
First Named Inventor	William John Testin
Examiner Name	
Art Unit	
Attorney Docket No.	PU030338

METHOD OF PAYMENT *(check all that apply)*

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Deposit Account Number: 07-0832

Deposit Account Name: THOMSON LICENSING INC.

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	160

SUBTOTAL (1) ($) 160

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims	16	- ** =	16	X		=	0
Independent Claims		- ** =	0	X		=	0
Multiple Dependent				X		=	0

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

***or number previously paid, if greater; For Reissues, see above*

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet.	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive – unavoidable	
1453	1,330	2453	665	Petition to revive – unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17 (q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR § 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR § 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0

SUBMITTED BY		Complete *(if applicable)*			
Name (Print/Type)	Robert B. Levy	*Registration No. (Attorney/Agent)*	28,234	*Telephone*	609/734-6820
Signature				*Date*	Dec. 30, 2003

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PROVISIONAL PATENT APPLICATION
ATTORNEY DOCKET PU030338

Modified Control for Thermistor Operated DC Fan

The invention consists of a low-cost variable speed temperature-controlled fan with a programmable response curve of temperature vs. speed. The invention modifies the input circuit on a variable speed "thermistor-controlled fan" to instead allow the speed to be controlled by a voltage source or a variable pulse-width current sink.

An electronic package used in an HDTV Receiver was found to have different thermal properties based on its orientation in an instrument, and based on what features are included. The application needed a low-cost variable speed temperature-controlled fan with a programmable response "curve" to be able to compensate for the different thermal characteristics. The least expensive option, a thermistor controlled fan, did not allow fan speed to be modified based on orientation of the module in the final instrument. The proposed circuit utilizes the low cost "thermistor" controlled fan, but allows the temperature vs. fan speed to be programmed in the instrument assembly plant based on orientation.

Commonly used low-cost variable-speed fan options are:

1) A single-speed 2-wire fan: The fan speed is controlled by a PWM that is integrated in an Opamp. The variable DC voltage from the Opamp drives the power supply pin for the fan. By controlling the supply voltage, the speed of the fan can be varied. This method requires numerous parts (a PWM generator, power Opamp, etc.), and is very inefficient at low speeds (when the fan is operating at less than the Opamp supply voltage, the power is dissipated by the Opamp). It also has issues with the startup voltage; each fan vendor has a different minimum guaranteed startup voltage.

2) A direct PWM drive 3-wire fan: This method is more efficient with power and parts than option 1) above, but is typically more expensive. A direct PWM drive 3-wire fan is $0.25 to $0.50 more expensive than a typical thermistor-controlled fan.
3) A single-speed 2-wire fan can used with a PWM controller to drive a switch in series with the power supply leads. The PWM controls the duty cycle of the current in the fan, which regulates the speed. This method is cost effective and power efficient, but switching the internal control IC

in the fan may result in reliability problems. Most vendors do not guarantee their fan when operated in this manner.

4) The most cost effective variable speed fan is a thermistor-controlled 3-wire fan. The disadvantage of it is that the "curve" that controls the fan speed vs. temperature is fixed by the thermistor. In the case of module orientation, for instance, two or more different thermistor characteristics are needed. There are several options to work around the problem.
If the details of thermal conditions are known, multiple thermistors can be used with a switch to enable the appropriate one. One example would be to use an NPN transistor as a switch to enable one of the thermistors. The base of the NPN transistor could be driven from a microprocessor, and the micro could read an EEPROM bit to determine which switch should be closed. In the case of a TV, the EEPROM could be programmed by an IR Remote with a factory-initiated command.

b) A second option is to build multiple versions of the module, one with thermistor type A, one with thermistor type B, etc. The main drawback of this configuration is the expense of building and stocking multiple versions of the module. In addition, this method doesn't allow the characteristic of the temperature vs. fan speed to be modified after the original design is complete. As an example, if one model has more audio power than the base unit, the ambient temperature in one area of the instrument might be higher which would warrant a higher fan speed in a different area of the instrument.

5) This invention takes the thermistor-controlled 3-wire fan and replaces the thermistor with an external temperature-measuring device and controls the speed with a variable DC voltage or a variable current source. By replacing the traditional thermistor with a variable DC voltage or variable current source, an inexpensive fan can be used and the fan speed vs. ambient temperature curve can be programmed at any time during the development or assembly of the module.

The invention takes a low-cost 3-wire "thermistor-controlled" variable speed fan and replaces the thermistor with a variable current source. (See Figure #1) The thermistor-controlled fan (U1) is controlled by the voltage at the junction of two series resistors (R1 and Rf). The main power

supply for the fan in this example is 12V. The series resistors are typically connected between a fixed voltage supply (V1, typically 6V) and ground. The voltage at the junction of the resistors is fed to the input "A" of a voltage to current controller. In order to turn the rotor on the fan, a "rotating field" is needed through coils 1-4. This rotating field in the fan housing opposes a fixed magnet in the rotor of the fan. The fan speed is controlled by the peak current at the end of each pulse cycle of the rotating field. By controlling the voltage on the 3rd wire of the fan, the peak current on each cycle can be controlled which then controls the speed of the fan. In order to vary the fan speed, the voltage at node "A" needs to vary based on the ambient temperature. The variable voltage is obtained by replacing the lower resistor R1, with a thermistor. A thermistor is a resistor with a material that has a specific resistance vs. temperature characteristic. As an example, in our application, the resistance of the thermistor is 10K ohms at 25 degrees C and 5K ohms at 40 degrees C. As the temperature surrounding the thermistor increases, the resistance of the thermistor drops and the voltage at the center of the resistor divider drops. In the case of the fan controller, the fan speed is inversely proportional to the applied voltage, so as the voltage decreases the voltage to current converter then increases the peak current in each cycle to increase the fan speed.

In option 1 (see figure 2), the fan control consists of a single resistor R1. The resistor R1 is in series with an N-Channel Mosfet. The Drain of the Mosfet is connected to one end of a resistor and the Source is connected to ground. A PWM circuit generated in an FPGA controls the gate of the Mosfet. An LM77, (an IIC controlled temperature measuring IC) is used to monitor the ambient temperature around a POD (Point Of Distribution) smart card-like device. A microprocessor is used to periodically read the ambient temperature from the LM77 over an IIC Bus, and then sends the appropriate PWM duty cycle to the FPGA based on the specified temperature vs. voltage table. The PWM output (typically 0-3.3V) then controls the duty cycle that Q1 is "on". When "on", drain to source current flows through Q1 and resistor R1 is connected to ground. By controlling the time that the resistor is grounded, the average current seen by the control wire on the fan can be varied.
To control the speed, the PWM was run from the maximum duty cycle 31 out of 32 steps (5 bits) at the gate of Q1 to roughly 16 out of 32 steps (50% duty cycle). Since the maximum duty cycle results in the Q1 being turned on almost 100% of the time, R1 appears to be continuously. In the

case of minimum speed, the 50% duty cycle generates an average current equivalent to roughly 10K. By varying the duty cycle from 50 to 100% results in min to max speed.

In testing the circuit, the min PWM value had to be controlled to prevent the peak voltage seen on the Drain of the Mosfet to be less than the 3.9V rating on the FPGA. With the fan we were using, the control pin floated to 6V when the control line was open circuit. To prevent an over voltage problem, a Schottky diode D1 was connected from the drain of Q1 to the 3.3V supply of the FPGA. The diode limits the peak voltage on the Drain to 0.4V above 3.3V supply. To save cost, the Mosfet was an "open-drain" output of the FPGA, rather than a discrete Mosfet.

Option 2 (see Figure 3) was developed to eliminate the diode and to allow the full range of the PWM to be used. It uses the same concept as Option 1, but adds a second resistor R2. R2 allows a minimum current to be set up which limits the maximum voltage seen by the Drain of the Mosfet. R1 then just controls the additional current needed to run the fan from maximum to minimum speed. The fan we used was specified to have a 10K impedance at 25C and 5K impedance at 40C. By setting R2 = 10K and R1= 10K, we were able to linearly control the current in the fan control line from 10K (the PWM at 0% duty cycle) to 5K with the PWM at 100% duty cycle. The voltage at the control input to the fan ranges from 2.9V at 10K to 1.9V at 5K. The internal circuitry in the fan then uses this voltage variation to vary the fan from its minimum speed 800 RPM to its maximum speed 2000 RPM. In addition to eliminating the voltage problem on the Drain, Option 2 also eliminates the need to limit the range of the PWM since the full range is useable.

In testing Option 1 and Option 2, it was found that the fan produced an audible noise at the PWM period that was somewhat modified by the duty cycle. In order to minimize this affect, the PWM period was kept above 20KHZ where the switching noise was not audible.

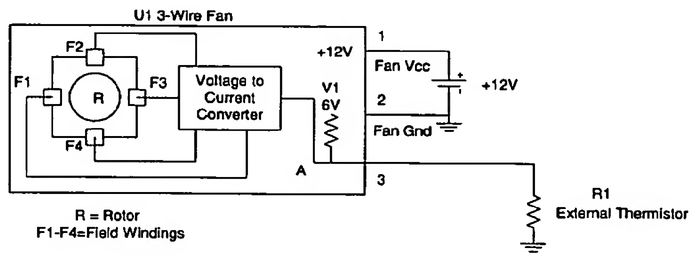
Option 3 (see figure 4) is similar to Option 2 with the exception of the addition of C1. C1, which is in parallel with R2, integrates the average current through R1 in parallel with R2. This eliminates the time-varying signal at node "A". The main advantage to the addition of C1 is the elimination of any frequency dependence on the PWM. The PWM can be run as slow as a few kilohertz without any audible noise. A typical value of C1 is 10uF.

Option 4 (see figure 5) uses Option 3, but adds Q2. Q2 is an NPN transistor that allows the fan to be turned off when not needed. One of the problems with the thermistor-controlled fan design, it that the minimum speed of the fan is roughly half of the maximum speed. The fan speed cannot be reduced below 50% or turned off. To minimize noise in the application, especially when the set was turned off, a second transistor Q2 was added. Q2 can be any switch, and in our case an NPN transistor was chosen. An I/O pin on the microprocessor controls the base of the NPN.

The present implementation has the microprocessor read the LM77 once every minute. The value is compared to a threshold that is stored in the EEPROM. If the measured temperature is higher than the threshold for 5 consecutive measurements, Q1 is turned on and Q2 is run at 0% duty cycle (min speed). If the measured temperature exceeds the threshold for 2 or more consecutive measurement, the fan speed is increased by one PWM step. There are a total of 32 allowable steps (5 bits) in this application, but any number could be used. In the case that the ambient temperature around the POD Card drops on four consecutive measurements, the fan speed is decreased one step. In the case that the minimum step of the fan has been reached, and the temperature is less than the threshold by a limit programmed in the Eeprom, the fan will be turned off by setting the base of Q2 low. The cycle described above continues from the time the software is booted until AC is removed. The ultimate goal is to have the temperature of the POD Card controlled to <65 C with the minimum amount of noise from the fan (which implies the slowest speed).

Options 1-4 were built up and tested. Option 4 was chosen to limit the risk of any problems in the fan due to the time-varying waveforms in Options 1 and 2, and it allowed the fan to be turned off when it wasn't needed.

TYPICAL THERMISTOR-CONTROLLED FAN



fan control figure 1a
WJT 12/20/03

Figure 1

VARIABLE PULSE-WIDTH CONTROLLED THERMISTOR FAN

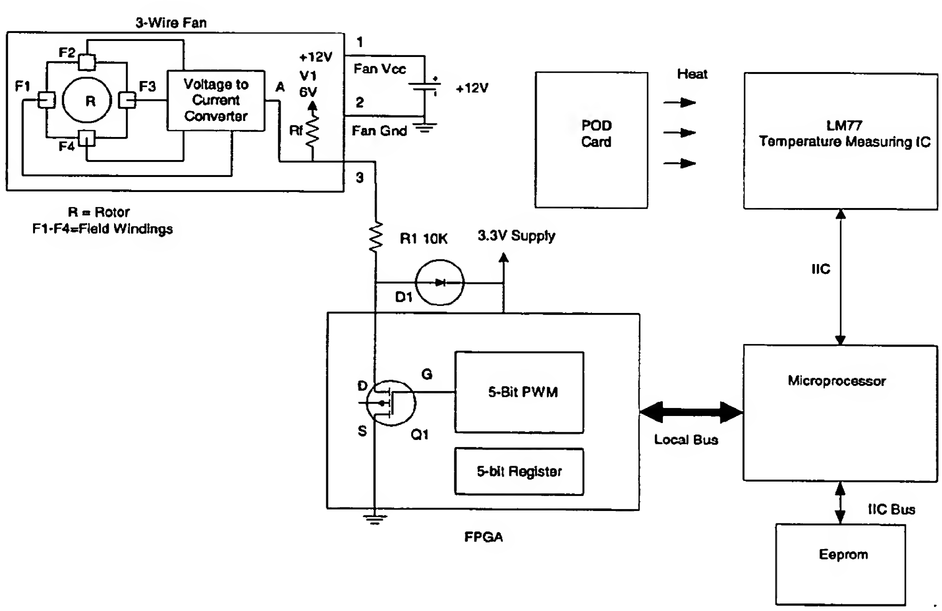


Figure 2
(Option #1)

fan control figure 2a
WJT 12/20/03

VARIABLE PULSE-WIDTH CONTROLLED THERMISTOR FAN

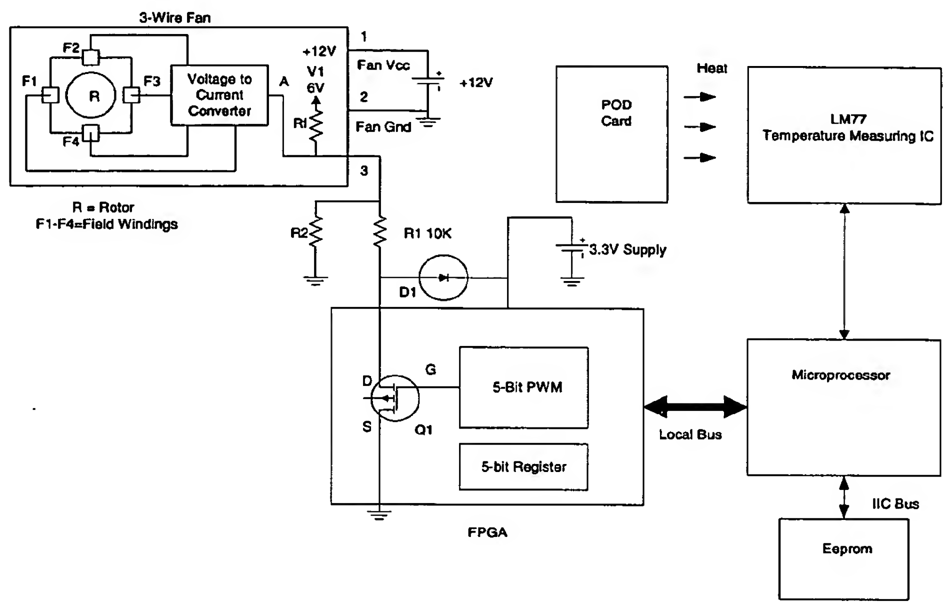


Figure 3
(Option #2)

VARIABLE PULSE-WIDTH CONTROLLED THERMISTOR FAN

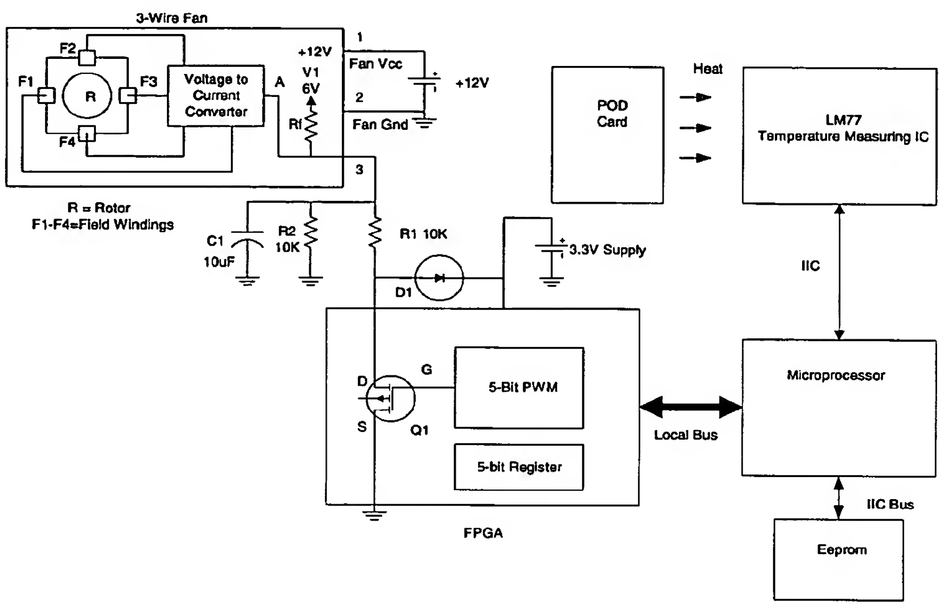


Figure 4
(Option #3)

fan control figure 4a
WJT 12/20/03

VARIABLE PULSE-WIDTH CONTROLLED THERMISTOR FAN

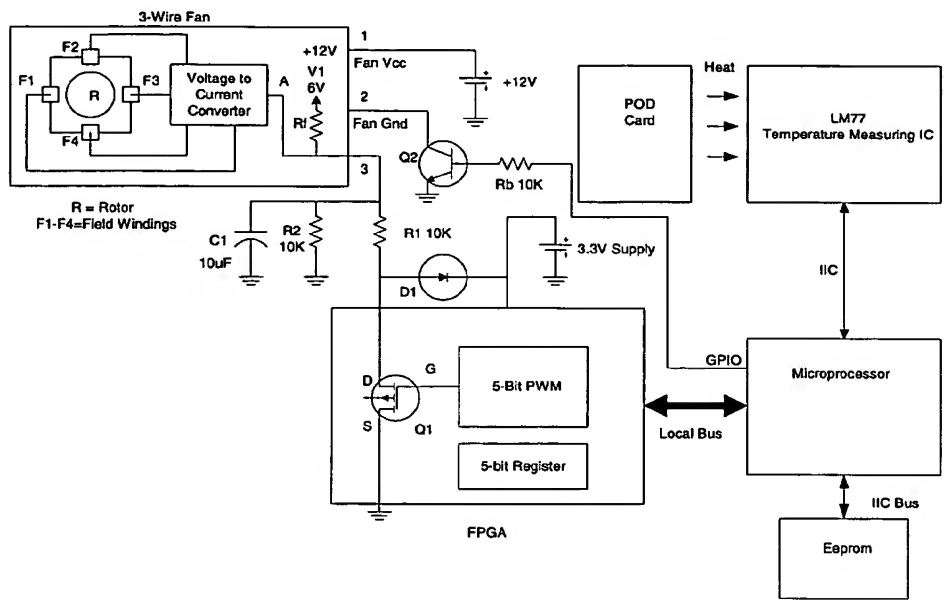


Figure 5
(Option #4)

fan control figure 5a
WJT 12/20/03